Preface

This book is a collection of resources for students of natural resource science and management[1]. Many of you will be required to complete some mathematics and/or statistics courses during your undergraduate studies, and some of you will likely dread the prospect.

[1] I interpret this broadly, so that we may include study of fisheries, wildlife, forestry, and water resources, among other things

However, if you're reading this, you have probably been presented with an alternative means of satisfying at least some of your quantitative skills requirements. This is the origin of the course NREM 240 at Iowa State University, for which this book was originally prepared. NREM 240 is a class about solving quantitative problems that non-mathematicians interested in biology and environmental sciences may find compelling.

I use the word *problem* here in the same way that math education scholar Alan Schoenfeld does — to describe an intellectual challenge that is quantitative in nature[2]. A problem is distinct from an exercise in subtle, but crucial ways. An exercise is a prompt for which a student must select one or more of a small number of recently-demonstrated procedures or algorithms to reveal a clear and known[3] result. Contrast that with the intellectual impasse of Schoenfeld. In this spirit, a problem is a deeper challenge that often contains a mixture of complexity, uncertainty, and ambiguity and requires some technical skill or knowledge. A problem also often requires creativity — or as Pólya says in the quote[4], "inventive faculties" – and the willingness to explore, to try and fail, to persist, and to learn from mistakes. This kind of task can be frustrating and uncomfortable for those of us not accustomed to it, particularly if we have no interest or investment in the problem being posed. But life rarely provides us with exercises. If we *are* confronted with exercises, we become bored and uninspired by the idle redundancy[5]. But a completely different sense of achievement and satisfaction is realized when we solve problems because, by their very nature, they lead us to new ways of thinking and understanding, if we are willing.

[2] Schoenfeld, A. H., 1985, *Mathematical Problem Solving*, Academic Press.

[3] at least to the instructor and the owner of a solutions manual

[4] Excerpted from the preface of Pólya, G., 1945, *How to Solve It*, Princeton University Press.

[5] Mathematician Paul Lockhart has written an engaging, though scathing critique of current school math curriculum in a book called *A Mathematician's Lament*.

NREM 240 at ISU was initially conceived as a bridge to link the quantitative skills developed elsewhere with some common applications in the natural sciences. Experience has shown that, once students know which techniques to apply to which given quantities, the computational task is rarely challenging. A greater challenge is the selection of appropriate techniques and assembly of relevant input quantities when neither are given. Since both of these processes are hallmarks of authentic problem solving, NREM 240 evolved to embrace the problem-solving process as the central objective, calling upon quantitative concepts and techniques as needed to address particular problems. Therefore, applied problems and the strategies used to address them have become the focus of the course, and this text has evolved to support that focus.

The philosophy of this text has been strongly influenced by John Harte's fantastic books, *Consider a Spherical Cow* and *Consider a Cylindrical Cow*[6]. Both books pose environmentally-themed problems that are compelling and maddeningly open-ended. But Harte boldly demonstrates how idealizations, approximations, and analogies can be leveraged to make sense of complex problems. On a tip from a friend in grad school, I picked up a copy of each of these books and was amazed. I had always been an average or slightly-below-average student of math all the way through grade school and college, and had never enjoyed it. Harte's problems hooked me because they offered a means to address problems I found compelling. I saw, perhaps for the first time, a way that math could help me gain insights into things I already wanted more insights into. I experienced an unfamiliar willingness to labor over unit conversion details, to really wrestle with what it meant to integrate a function, and to chase wild and risky ideas to see where they led. That feeling has stuck with me over the years, and I have sought to facilitate some semblance of that experience in the students I now teach.

[6] Harte, J., 1988, *Consider a Spherical Cow: A Course in Environmental Problem Solving*, Sausalito, CA, University Science Books; Harte, J., 2001, *Consider a Cylindrical Cow: More Adventures in Environmental Problem Solving*, Sausalito, CA, University Science Books.

The methods or strategies that are highlighted here are drawn in large part from 's problem-solving framework and derivatives thereof. Excellent tutorials on problem-solving include *Thinking Mathematically* by Mason, Burton and Stacey[7], *Crossing the River with Dogs* by Johnson, Herr, and Kysh[8], and *Ants, Bikes, and Clocks* by Briggs[9]. Notwithstanding the odd titles of some of those books, all provide interesting perspectives and tips for problem-solving. Even so, many of the problems in these texts are of the sort that you might find on standardized tests: "Janet leaves on a train heading east at 42 miles per hour, while Mark...". If there is truth to the idea that we embrace challenges when they address topics that we are already interested in, these approaches may still fail to engage students. With this in mind, the examples and exercises in this text are aimed at engaging the natural resource student in thinking about for-

[7] Mason, J., L. Burton, and K. Stacey, 2010, *Thinking Mathematically*, 2nd ed., Pearson Education Ltd.

[8] Johnson, K., T. Herr, and J. Kysh, 2012, *Crossing the River with Dogs: Problem Solving for College Students*, 2nd ed., Wiley.

[9] Briggs, W.L., 2005, *Ants, Bikes and Clocks: Problem Solving for Undergraduates*, Society for Industrial and Applied Mathematics.

est measurements, fisheries management, habitat conservation, and the like.

You will find in the pages that follow an introduction to problem solving *as a process*. You'll also find a review of some frequently-used mathmatical concepts and procedures. For some of the more powerful concepts and techniques, exercises are provided to assist with reviewing (or exploring for the first time) by doing. The booklet is not intended to be a guide to be followed through a series of skills, but rather a resource to support the problem-solving process and help lower the conceptual and computational barriers along the way.

Schoenfeld argues that what constitutes a problem to you depends strongly upon your experience and formal training. This relativity makes it challenging to keep a diverse group of students on the same page, and able to succeed at similar rates. With this in mind, in preparing the materials for this book and the course it supports, I have presumed 1) that you are sincerely interested in the natural sciences; and 2) that you have had a typical sequence of high school math courses, including a few years of algebra, some geometry, and perhaps trigonometry and statistics. It may also be true that you have found it challenging or even unpleasant when asked to recruit your quantitative skills to interpret information or address a question in the coursework in your discipline. If any of this describes you, you're in the right place. Let's go!

Note to instructors

I have written this book with my students and their needs in mind, but hope that others may find it useful. It may be worth taking a moment to clarify how I use this book. While I expect my students to read this text and work on the exercises in it, I build the course around a group of "focus problems" not contained here, but with an open-ended form and practical flavor like the sample problems in Chapter 3. As we work on the first focus problem, I guide students through the problem-solving process described in Chapter 2, making frequent reference to examples contained in the book. Therefore, to appreciate the processes involved, I think it is wise to have students read the first three chapters early. The remainder of the book is organized more by problem type, and can be assigned or referred to as appropriate to support the focus problems, rather than proceeding linearly through each chapter.

I have deliberately avoided discussing particular software tools or internet resources, partly in the interest of ensuring that this text does not rapidly become obsolete, but also to allow for flexibility. In online video tutorials and in-class exercises, I ask my students to work with data and create graphs using spreadsheets, but those seeking richer computing environments can just as easily use this text alongside instruction in R, Matlab, Mathematica, and others.